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Fluorescent Microscopic Imaging: An Experimental Technique for Quantitative Visualization of Subsurface Contaminant Transport

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A novel nonintrusive measurement technique, fluorescent microscopic imaging (FMI), has been developed for 3D visualization and quantification of contaminant transport processes in subsurface. The experimental setup consists of a transparent porous column packed with clear mineral particles of various shapes and sizes in an aqueous refractive index-matched fluid. The refractive index-matching yields a transparent porous medium, free from any scattering and refraction at the solid-liquid interfaces, as a result allowing direct optical probing at any point within the porous system. Seeding the fluid with fluorescent microtracers or an organic fluorescent dye permits planar slices of the porous medium to be successively excited with a sheet of laser light. Contaminant transport processes through the porous medium can be observed microscopically, and qualitative and quantitative in-pore transport information can be obtained at a high resolution (several microns) and a good accuracy (2%). A computer controlled CCD camera is used to record the fluorescent images at every vertical plane location while sweeping back and forth across the column. These digitized flow images are then analyzed and accumulated over a 3D volume within the column. Series of flow experiments have been performed covering a wide range of flow conditions. Microscopic values of flow velocity, contaminant concentration, and pore geometry have been obtained at a resolution of more than 300,000 measurement points per given time. These results furnish unique predictive tools on subsurface contaminant migration as a function of porosity, grain heterogeneity, and flow velocity.

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